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13. ABSTRACT ***(Maximum 200 Words)***
A material's potential fire hazard can be quantified by the rate at which fire spreads over its surface under the influence of forced air convection. If the direction of air flow is the same as the direction of fire propagation, then the fire spread is termed "co-current." If the air flow is opposite to the direction of fire spread, it is termed "countercurrent." The worst-case scenario in a fire would be purely co-current spread. Consequently, several researchers have studied the rate of fire spread under co-current conditions. A question then arises about fire-spread rate under countercurrent conditions. Fire spread over polymethylmethacrylate (PMMA) under counter-current air-flow conditions has been studied. The study was carried out with two different thickness (0.0031 m and 0.0063 m) of PMMA and four different air-speeds (nominally 0.45 m/s, 0.75 m/s, 1.0 m/s and 1.15 m/s). The results indicated that the flame-speed is greater over the thinner sample than over the thicker one. PMMA, commonly called plexiglas or acrylic in fire-spread studies, was used in this study because it has well-defined thermodynamic properties like density, specific heat and heat of combustion and leaves behind little solid residue.

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Annual Report

Droplet Interaction with Hot Surfaces

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1. Project Objective

To obtain data and understanding of interaction of droplets with burning surfaces required to engineer improved heterogeneous agent dispersion systems with enhanced fire-extinction capability.

2. Technical Approach

Conduct experiments with non-evaporating and evaporating particles of controlled density injected at controlled velocities towards a variably heated surface. Obtain probability density functions of the variation in particle velocity as a function of the impressed buoyancy forces, thereby determining the effects of flame buoyancy on the likelihood of a particle reaching a burning surface. Determine the effect of evaporation on these results. Conduct experiments with mono-disperse and poly-disperse droplets injected over the flames from PMMA or over heated polyurethane foam, using droplet loading, delay time after ignition, and location of the spray from the leading edge as parameters. Obtain reduction in flame spread so as to obtain empirical correlation between spray characteristics and flame spread. Use Two Color Planar Pyrometry to measure surface temperature changes as a function of aerosol impingement. Conduct Monte-Carlo simulations of the mist/surface interactions to develop fuller understanding of the dominant processes and identify the key aerosol properties that impact efficient suppression of the fire.

3. Important Findings

A material's potential fire hazard can be quantified by the rate at which fire spreads over its surface under the influence of forced air convection. If the direction of air flow is the same as the direction of fire propagation, then the fire spread is termed "co-current". If the air flow is opposite to the direction of fire spread, it is termed "countercurrent". The worst-case scenario in a fire would be purely co-current spread. Consequently, several researchers have studied the rate of fire spread under co-current conditions. A practical fire scenario, however, has a mix of co-current and countercurrent conditions. A question then arises about fire-spread rate under countercurrent conditions. Fire spread over polymethylmethacrylate (PMMA) under counter-current air-flow conditions has been studied. The study was carried out with two different thickness (0.0031 m and 0.0063 m) of PMMA and four different air-speeds (nominally 0.45 m/s, 0.75 m/s, 1.0 m/s and 1.15 m/s). The results indicate that the flame-speed decreases as the opposing air-speed increases. The results also indicate that the flame-speed is greater over the thinner sample than over the thicker one. PMMA, commonly called plexiglas or acrylic in fire-spread studies, was used in this study because it has well-defined thermodynamic properties like density, specific heat and heat of combustion and leaves behind little solid residue.

During the tests, it was observed that the flame speed, after an initial transient, is approximately constant. The flame spread rates were measured during the constant phase of the flame spread. The mean velocities, determined for four different air speeds and two thicknesses of PMMA, were averaged to yield a plot of the overall velocity versus air speed as shown in Figure 1.

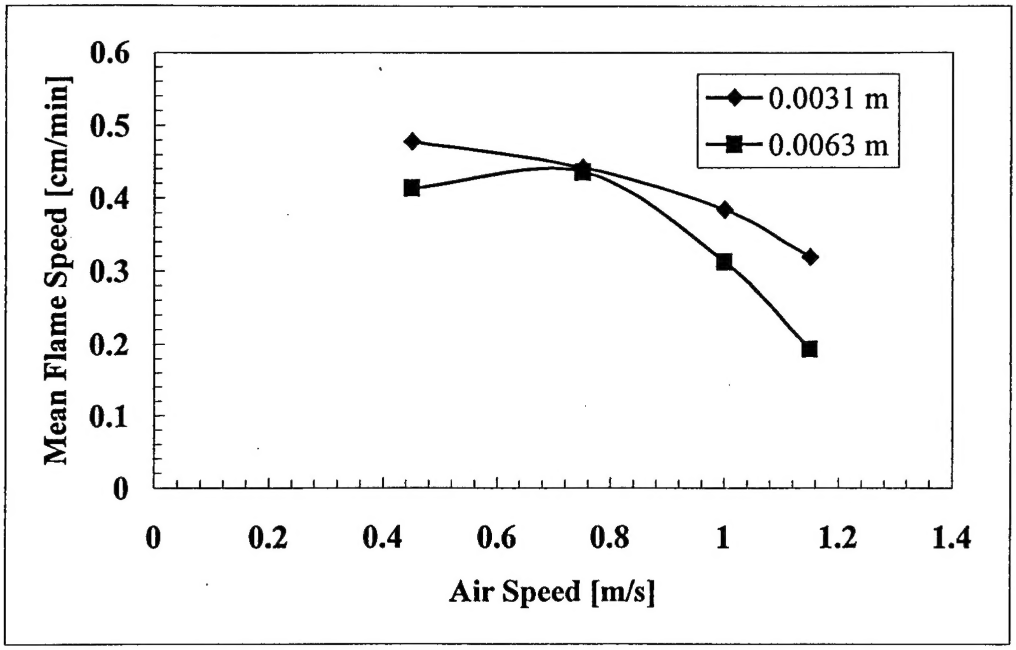

Figure 1. Flame spread rates for two PMMA sheets of different thicknesses.

Apart from the case of the 0.0063 m thick sample at 0.75 m/s air speed, the results indicate that the fire-spread speed decreases monotonically as the opposing wind-speed increases. This is expected. Figure 2 shows, for the 0.0031 m thick sample, the fire-spread rate decreases from 0.48 cm/min to 0.32 cm/min as the air speed increases from 0.45 m/s to 1.0 m/s. A similar trend is observed in the case of the 0.0063 m thick sample, where the fire-spread rate decreases from 0.41 cm/min to 0.19 cm/min as the air speed increases from 0.45 m/s to 1.15 m/s. Results also indicate that, for the same air speeds, the fire-spread rate over the thinner sample is higher than that over the thicker sample. The results are consistent with expectations. The flame-spread speed does decrease with increase in the opposing air-speed.

Flame spread experiments with mono-disperse and polydisperse spray of water are in progress. These results will provide empirical correlations for the optimum location, drop sizes and velocities for effective extinguishment.

4. Significant Hardware Development

A wind tunnel that was constructed for flame spread studies during the first year of the current project is shown in Fig. 2. The experimental apparatus consists of ductwork to contain the counter-flowing air, a mount for the PMMA, an optical system for tracking the flame front, and software for data acquisition and analysis. The 0.45 m x 0.76 m x 1.75 m long duct was made of aluminum sheet metal and mounted on a Unistrut® frame. The fan at the downstream end controls the air speed, which passes through 0.0063 m diameter and 0.25 m long honeycomb flow straighteners before passing over the test-piece. The interior of the duct is insulated with ceramic paper of thickness 0.0015 m from Cotronics, Corp.®

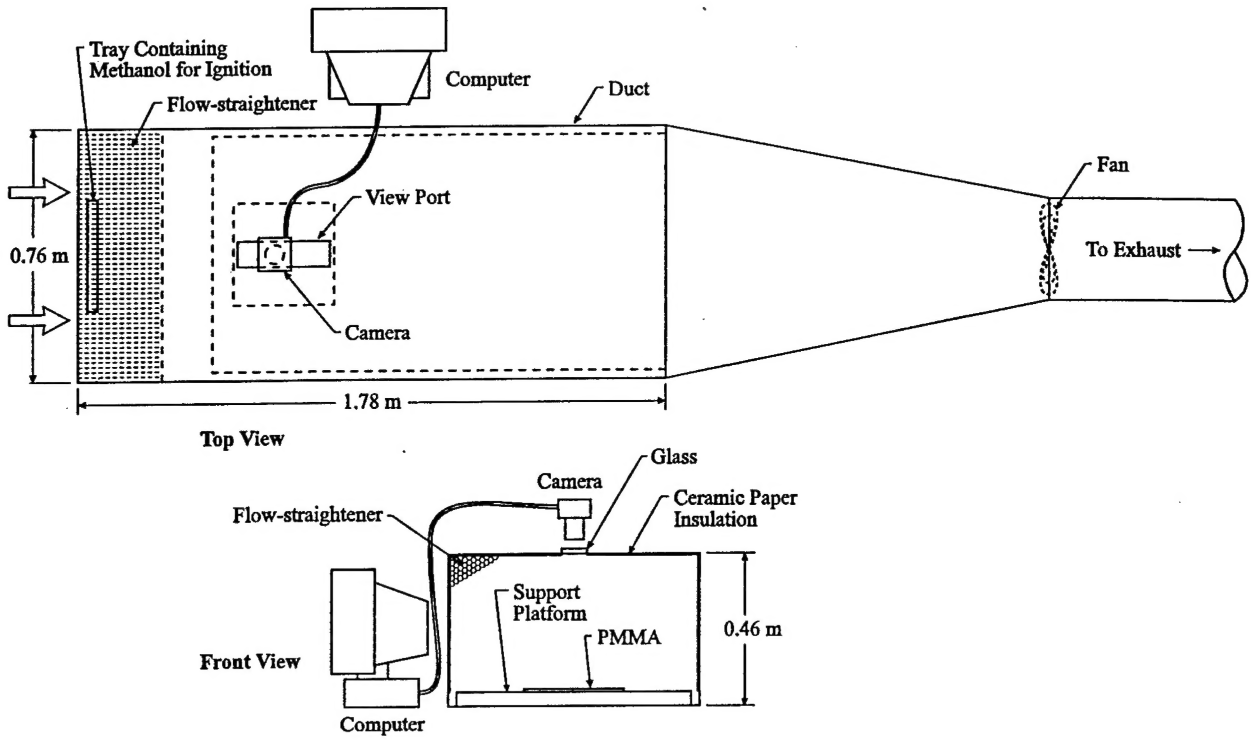

Figure 2. Wind tunnel used in flame spread experiments.

A CCD camera mounted on a frame above a slot in the upper surface of the duct is used for the Focal Plane Array Imaging. The images are captured 30 seconds apart and used to obtain the flame spread rate.

The second part of hardware development involved fabrication of a heated surface to obtain the simultaneous drop size and velocity distributions for a spray impinging a hot target. The schematic of the experimental arrangement is shown in Fig. 3. Initial drop size and velocity

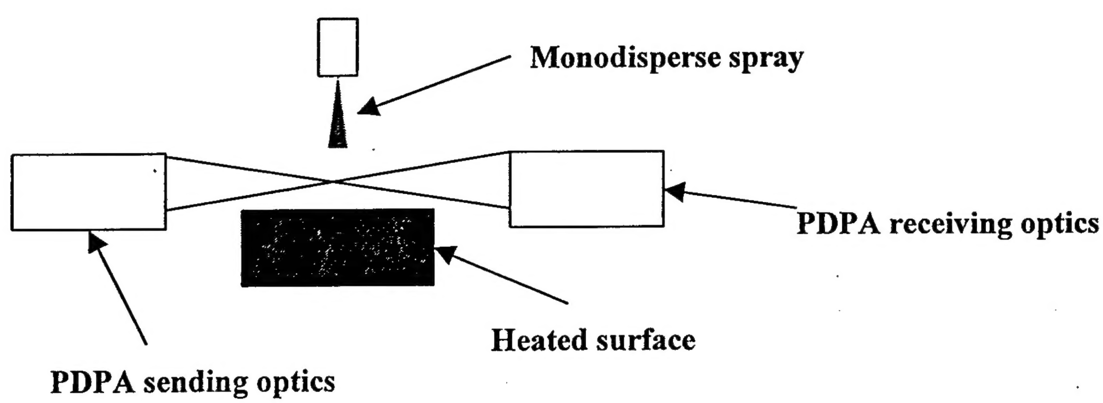

Figure 3. Experimental arrangement for PDPA measurements.

measurements are in progress. These measurements will provide a map of the velocity/drop size distributions that are capable of penetrating fires to reach the surface of the combusting material and their desirable physical properties. This research will provide desirable physical properties for improved fire suppression agents.

5. Implications for Further Research

The first part of the on-going research will provide the optimum method of delivery of suppressants to the fire location. This is important in designing the best suppression system with the available agent. However, the location of the fire will have to be determined by the suppression system to effectively utilize the information being generated. Therefore, for further research, suppression systems that can locate the fire is crucial.

The second part of the on-going research will provide the desirable physical properties of the suppressant. After these results have been obtained, improved fire suppressants should ideally be tailored to have these physical properties.